TECHNIAL ADVISORY COMMITTEE MEETING NOTES FROM MAY 9 & 10, 2017

The following are notes compiled from the Technical Advisory Committee meetings on May 9 and May 10, 2017. Slides are available for reference while reviewing the notes.

For questions, please contact Kalle Matso at kalle.matso@unh.edu

TECHNICAL ADVISORY COMMITTEE MEETING MAY 9, 2017

Participants

Facilitator: Kalle Matso, PREP Coastal Scientist
Rachel Rouillard (PREP)
Abby Lyon (PREP)
Dante Torio (UNH)
Brian Giles
Jud Kenworthy (external advisor)
Ken Moore (external advisor)
Chris Gobler (external advisor)
Toby Stover (EPA)
Wil Wollheim (UNH)
Jacquelyn Boudreau (FB Environmental)
Rich Langan (UNH)
Art Mathieson (UNH)
Paul Stacey (GBNERR)
Dean Peschel (consultant, City of Dover)
Dave Cedarholm (Tighe & Bond)
Ashley Norton (UNH)
Erik Sawtelle
Lindsey Williams (UNH)
David Miller (resident, City of Rochester)
John Hall (consultant, City of Dover)
Regina Lyons (EPA)
Bob Lucic (Sheehan, Phinney, Bass, Green)
Ken Edwardson (NH DES)
Ted Diers (NH DES)
Matt Wood (NH DES)
Rachel Stevens (GBNERR)
Michelle Shattuck (UNH)

Opening 10:05 AM

Introduction of "external advisors"
Jud Kenworthy (retired from NOAA; also served on 2014 Peer Review Report)
Ken Moore (Virginia Institute of Marine Science)
Chris Gobler (Stony Brook University)

SLIDE TWO: PREP'S TECHNICAL ADVISORY COMMITTEE TIMELINE (2016-2017)

Kalle: As you can see, we've arrived at Meeting 5 after four previous meetings over the past year.

SLIDE THREE: GOALS FOR TUESDAY AND WEDNESDAY COMBINED

Art: Say a little more about the cross-cutting section.
Kalle: In the State of Our Estuaries Report (SOOE), there is usually little opportunity to discuss how the different indicators (e.g., nutrient loading, dissolved oxygen, eelgrass, etc.) relate to each other. Also, there are other parameters (e.g., precipitation) that are not discussed. We're hoping that, by adding this cross-cutting section, we can address some of these issues.
Eric: Following Art's question, looking for possible correlations? Extension of that, where in the process, or are you going to talk about future issues or future correlations. Or different parameters?

Kalle: In the 2014 Peer Review Report, Ken Reckhow talked about classification trees. Looking at all the stressors and how they relate to each other. Don't have time for this SOOE, but need to move in that direction.

SLIDE FOUR: BASIC AGENDA FOR TUESDAY, MAY 9
Just a reminder that the TAC is a completely open process. Everyone is invited and everyone has equal standing.

SLIDE FIVE: BASIC AGENDA FOR WEDNESDAY, MAY 10
n/a

SLIDE SIX: INTERTIDAL SEAWEED
Kalle: We've talked about seaweed before, but if you're in the TAC review team, you may see this graph and say "it doesn't look like what we've seen before." David Burdick has been leading the seaweed monitoring and can speak to this.

David Burdick: Jeremy Nettleton (2008/09, graduate student) chose to show the 1979 data without the Piscataqua River sites (3 data points in estuary: Piscataqua, Wagon Hill, Great Bay Estuary). When I worked on this data, I added an end point, and included the Piscataqua sites. Doesn't look like a big change, but there are more brown algae.
In my view, the character of the seaweed species is changing. Most of the green now isn't Ulva. In 2009 it's primarily ulva and gracilaria. Showing the graph belies complexity of the situation. I believe the algae are changing in the bay, but when you just put a graph of reds, browns, and greens, this is the information you get. Doesn't look like a big change, but the characteristics are changing, in my opinion.
Jud: These are intertidal stations?
David: Yes.
Jud: So, with regard to subtidal, it's just anecdotal info?
Kalle: There are some exceptions; also, Fred Short has been doing work on seaweed at the SeagrassNet sites, but that data hasn't been reviewed sufficiently yet. It will be coming out soon though.
Rich: Even the casual observer would notice the proliferation of different types of macroalgae is spatially and temporally highly variable. How do we translate 5 sites to the whole system?
David: With lack of funding, we have to pick the sites very carefully. Have to make some choices. Would be great to sample everywhere all of the time, but we don't have the resources.
Ken: Certainly, you need a broader assessment of algal abundance throughout the system. One of the things coming out of this, from my perspective, is that we don't know all the things we need to know.
David: We don't even know what we need to know to set up a sampling scheme. First, this is intertidal, and maybe we should care about subtidal. This is an indicator of what might be happening in the subtidal. 10 people snorkeling would be great, but it gets expensive.

SLIDE SEVEN: PRECIPITATION

This data come from the Greenland station, which goes back to the 1970s, unlike the other stations. When you see this in the SOOE, it will change because I'll average it with other stations.

Process that we have for what you see in the SOOE report, we want to make sure it's correct. All the data is QA/QC'd so we know the data is correct. I've been developing the graphs and sending them to Matt Wood to have a second set of eyes on them.

Important point for precipitation, especially between 2005 and 2010, we saw higher than normal levels of precipitation. For the last 4-5 years, precipitation levels have been much lower.

John: Rather than average 3-4 stations, you may want to use the flow data from a few rivers. Gives you a better picture of how a little inch or two translates into river flow.

SLIDE 8: LAMPREY RIVER SPRING RUNOFF

River Discharge: Kalle

Lamprey river spring runoff cubic ft. per second. Summer runoff it's a little different. This is the kind of data that we need to be aware of. According to climate projections, our system is going to be dealing with more and more of this kind of activity that is pretty unusual, compared with the past. If we want our systems to withstand these sorts of changes we need to do what we can to make them more resilient.

SLIDE 9: fDOM AND SALINITY 2005-2006

This data come from the Great Bay Buoy, X-axis are months. April-November. Only have 5 years of data right now.

You can see a relation between CDOM and salinity. Huge storms and salinity drops and CDOM goes up. Questions?

Paul: Basically it's a dilution effect?

Rich: Disagree with that. Primary source of CDOM is landward. Rainfall washing CDOM into the estuary.

Jud: Note on these 3 graphs, in 2005 and 2006 there was a whole order of magnitude change in CDOM. Pretty extraordinary. What was going on in 2005 and 2006? Major flood?

Kalle: We had several big storms, including the 2006 Mothers day flood, which was a 100-year flood based on discharge from Lamprey River.

SLIDE 10: TURBIDITY 2005-2006

Turbidity is a measurement of the scattering of light in the water. Water clarity. Will also talk about light attenuation but that's derived differently.

Matt: Need to clarify one thing; it doesn't necessarily top out at 50, the meter measures to that extent. A lot of these values we had to qualify as "greater than 50." We are seeing spikes but we don't know how far they are going.

John: We feel there may be an Issue with the turbidity readings. Look at 2009/10 where it's just peaking out across the whole time. We don't believe those data are real. You'd have to have a continuous gale to be blowing to keep it stirred up like that.

Rich: Doesn't make sense to me since 2005 and 2006 were much higher rainfall, and the turbidity is much lower than it was in 2009/10.

Kalle: OK. I'll talk more with Matt Wood and we can discuss whether we feel comfortable using this data.

SLIDE 11: LIGHT ATTENUATION ADAMS POINT

Light Attenuation: Kalle

Measure light at different depths and then do a regression to get a Kd value. The higher your Kd the worse the light. When we do eelgrass maps, we are supposed to wait for days when the clarity is really good, which means less than 1 Kd. Adams Point (grab samples/month) lots of variation. But what you see (box and whisker plots) is the full extent of the data.

John: Looking at this data set, there's something screwy with the 2013 reading. 2006 certainly had the worst transparency. 2013 had way less flow. Can't imagine how that number could have occurred.

Also, these were low tide data, not the average Kd over the tide cycle. So this is the worst Kd. The other Kd would be at high tide and it would probably be the best Kd.

Jud: What depth is this taken at?

Rich: not sure who collected this data, but if they were sampling at Adams Point it would be at a depth of 5m.

SLIDE 12: LIGHT ATTENUATION GREAT BAY

Kalle: This is data from the Great Bay station, as opposed to Adams Point.

SLIDE 13: NUTRIENT LOADING

Nutrient Loading: Kalle

Michelle is working very hard to break out this graphic so we can see it annually instead of in these multiple year periods. For the last period, there is more change than is represented in this graph. We have 4 other upgrades in process right now. Newmarket might be 4mg/L, Portsmouth and Exeter are in process, Durham is doing some pilot work to see if they can reduce nitrogen. Other, unfortunate thing here is that It only goes back to 2003. We wish we could go back further…but we don't have that data.

Jud: The blue is non-point sources? Do you know the sources of those?

Michelle: A lot of that information is in the Great Bay Non-Point Source Study (http://scholars.unh.edu/prep/381/).

Matt: Changes for each watershed. Town level, watershed level. Atmospheric deposition, fertilizer, pet waste, sewer. Fertilizer around 13-18%...

Eric: Looking at this graph (Nutrient loading) and the reduction in eelgrass over the same period. Do we know what the optimum level of nutrients are? Not just N but P too. How do you distinguish what is nutrient enrichment, eutrophication, or a deficit? It may support other species (reds, or ulvas), but how do we know what that optimum level is?

Ken: Recall that these systems developed in environments with low nutrients. Most nutrients come from the sediments and are well recycled. Hard pressed to have a system that is stressed by not enough N; most are well adapted for low N in water column and when N gets elevated it's when we start to see issues.

Kalle: Loses competition from seaweed because seaweed gets N from the water column.

Ken: Eelgrass can get some N in the water column, but most from sediments. In Greenland, in the arctic, for example, there are dense eelgrass beds but there is undetectable N in the water column.

SLIDE 14: GOALS FOR THIS PRESENTATION
OK…switching gears now. The next two items on the agenda are 1) a talk from me on eelgrass stressors and then 2) a talk from John Hall of the municipal coalition on the same topic.

SLIDE 15: WHY THIS DISCUSSION? WHY THIS EXERCISE?
Kalle: Not going to get into discussion during the presentations. Allow questions for clarification. Trying to get through the presentations/discussion and then a break.
Why this discussion? Eelgrass and N loading has been a divisive and controversial issue in our community.
People continue to interpret the past 8 years in vastly different ways
Hard to approach consensus on the SOOE without dealing with this issue.

SLIDE 16: MATRIX TOOL
Matrix tool: going over how to complete the matrix. The X-axis is where you list the different things that could be stressing eelgrass. The first y axis is the probability that the stressor is important. The second Y axis has to do with the impact of the stressor. Some stressors have more impact than others. Think of this in a step-by-step process. 1) Is it plausible that the stressor is having enough impact that we need to think about management? 2) If plausible, what's the probability that it's a stressor that needs to be managed? 3) What's the potential impact? And 4) what's my confidence in this assessment? This is important because, for some of these stressors, we don't have that much information.

SLIDE 17: GREAT BAY EELGRASS
Kalle: A couple of introductory remarks. As many of you know, much of the data we have on eelgrass in our system comes from Fred Short's research. We had hoped to have a presentation from Fred today, but he is unable to make it today due to a very painful back problem.
At the outset here, I'll also say that my talk is going to focus mostly on Great Bay proper, as opposed to the rest of the Great Bay Estuary or the Hampton-Seabrook estuary.
OK…let's talk about eelgrass history.
Looking at eelgrass in terms of number of acres, we see that previous to the early 2000s, eelgrass sometimes decreased, but it recovers. After 2000, it decreases again and then recovers but not as high as previously. Then, in 2005 through 2007, levels really plummet. We know that those years had a lot of precipitation, and that leads to increases in many stressors, such as: more run-off, more salinity fluctuations, more nutrients, more CDOM, etc. After this period, we have a major drop in eelgrass and we see a pretty anemic recovery after that.

SLIDE 18: MATRIX TOOL
Kalle: So, the first thing I want to talk about is light reduction, as shown up here on the matrix.

SLIDE 19: REDUCING LIGHT TO EELGRASS LEAVES
Kalle: This graph shows the light attenuating substances in the water column. There's total suspended solids (TSS, which is mostly sediment but also plant and algal particles); the "color" is another way of referring to chromophoric dissolved organic matter, or CDOM. The "chl a" refers to chlorophyll-a, a pigment measured as a proxy for phytoplankton. "Drift" refers to any seaweed that becomes unattached and drifts in the water column, blocking light from eelgrass. And the "epiphytes" refer to algae and other organisms that attach to the blades of eelgrass and block the light in that way.

SLIDE 20: REDUCING LIGHT TO EELGRASS LEAVES
Kalle: This graph is adapted from a poster from Kenworthy and colleagues. In this graph, the red diagonal line creates an area (closest to the origin) of acceptable conditions for eelgrass. This graph is hypothetical but it's possible to create a graph like this for the Great Bay Estuary that is based on empirical data. This could be a very worthwhile exercise for our area.

The point that Kenworthy makes with this graph is that TSS, chl-a and CDOM (which is held constant in this model) should be thought of as additive. Because of that, sometimes you need to manage more than just the one component that is causing the most light attenuation…in order to get into the zone of acceptable conditions.
Jud Kenworthy: Just to clarify that this is a 2D representation of a 3D model. If you have data that shows CDOM fluctuating, you can represent that as well.

SLIDE 21: IS LESS LIGHT GETTING TO EELGRASS LEAVES? (light attenuation at Adams Point)
Kalle: Again, this is light attenuation at Adams Point. There isn't a significant relationship of change over time. On the other hand, many of the values are higher than is ideal for eelgrass growth.
Ken: Are these monthly measurements?
Kalle: Yes. And we know that there is a lot of variability and so these provide only a few snapshots in time. Lots of need for more data.
Jud: In particular, what's relevant to eelgrass is light during the growing season.
Kalle: Yes, these data are for April-December.
John: Whenever you plot any of this data, if you want to say it's related to eelgrass changing, you should plot the eelgrass.
Chris: Any data prior to 2003?
Kalle: Not on light attenuation.
Wil: Has anyone done a study of light attenuation in eelgrass beds?
Ken: I can speak to work done in other systems…not the Great Bay Estuary. It depends. Could be related to background water that goes over those systems. Or it could be not at all related…not a good estimator. John made a great observation about looking at eelgrass and light attenuation. You could have smaller cycles that you are missing in the monthly grab samples. When you start relating those two you don't see as good a fit as you think because the mechanisms are at different time scales.

John: There are additional data set. There is a Secchi disk dataset that you can use to correlate to the Kds and look further back in time. Pretty much looked like this…it bounced. (Kalle to follow up).

SLIDE 22: IS LESS LIGHT GETTING TO EELGRASS LEAVES? (light attenuation at Great Bay station)
Kalle: Again, looking at light attenuation data…this time for Great Bay.

SLIDE 23: IS LESS LIGHT GETTING TO EELGRASS LEAVES? (acres of eelgrass in particular depth regimes)
Kalle: This is a graph produced by Matt Wood of DES. Acres of eelgrass looking at eelgrass change based on depth during the years 1990-2013. The top line is for the deepest eelgrass and you see that it lost the most acres in 2006-2007 and also that the relationship of lost eelgrass with time is strongest for the deepest eelgrass. When eelgrass in deeper water is doing worse or moving to shallower water, it's usually an indicator of a problem with light.
John: Clarification. What you stated is a little misleading because the % decrease in each area is essentially the same. Shallower water had a 50% decrease, deeper water at 40% decrease, and middle around 35% decrease. 2006 only dropped in deeper water. That's why the rest of the graph goes further down and matches up against the red.
Jud: Another thing to consider. You can also plot the depths on the Y axis so that you create a hypsograph. That could give you more insight into where eelgrass is decreasing. It could be that the slopes are different at different elevations. Not many people are doing this, but some are.

SLIDE 24: IS LESS LIGHT GETTING TO EELGRASS LEAVES? (evidence suggests this may be happening)
Kalle: So, is less light getting to eelgrass leaves? It's inconclusive in terms of change over time, but most of the data suggest that light could be limiting in the Great Bay Estuary. So…looking at the matrix…

SLIDE 25: MATRIX TOOL
Kalle: ….the light attenuating components—CDOM, TSS, phytoplankton, drift seaweed and epiphytes—should all be regarded as important potential stressors. Let's look at these individually. First of all, with regard to epiphytes, we really don't have the data analyzed to offer insight on this stressor. So, as you see above, I've just marked it with a red square and a question mark.

SLIDE 26: SEAWEED (IN PARTICULAR DRIFT SEAWEED)
Kalle: Let's talk about seaweed. This photo is from Fred Short and comes from one of the three SeagrassNet transects in the Great Bay. It's important to note that seaweed exhibits a strong seasonal signal and usually peaks in the late summer/early fall.
In this picture, you an see some eelgrass, particularly in the bottom left area, but that area also has lots of Ulva; Ulva is dominant throughout actually and, in the upper areas of the quadrat, you see a lot of red algae, much of which is an invasive seaweed.

SLIDE 27: INTERTIDAL SEAWEED (IN PARTICULAR DRIFT SEAWEED)
Kalle: Graph on seaweed from David Burdick, which we talked about before. We wish we had more information, but the information we have makes us concerned. We could have a dramatic increase, particularly in the red and green alga.

SLIDE 28: MATRIX TOOL
Kalle: Graph on seaweed from David Burdick, which we talked about before. We wish we had more information, but the information we have makes us concerned. We could have a dramatic increase, particularly in the red and green alga.

SLIDE 29: PHYTOPLANKTON (chlorophyll-a concentrations at Adams Point)
Kalle: So, let's talk about phytoplankton. This graph shows phytoplankton at Adams point from 1989-2015. These are monthly grab samples. A lot can happen in 4 weeks that we don't capture but this is what we have. There is no statistical trend here, but it does seem that the levels were higher in the first decade of the 21st century as compared to the 1990s.

SLIDE 30: PHYTOPLANKTON (chlorophyll-a concentrations at Great Bay)
Kalle: This is Phytoplankton at the Great Bay station; this dataset only goes back to 2002.
Ken Edwardson (DES): Just want to point out that this is looking at the middle of the channel in the Great Bay; this is not looking at what is coming out of the tributaries. When you look at that data, you see a wider range of values than what you're showing.

SLIDE 31: PHYTOPLANKTON (Morrison et. al, 2008 – Turbidity & CDOM)
Kalle: This graph comes from Morrison et al 2008 (http://scholars.unh.edu/prep/110/). Ru Morrison now directs NERACOOS and he's hear with us today. These data come from the Great Bay Buoy. Left Y-axis black dots, right is the grey. Look at phytoplankton on the right (grey dots). What you see is sometimes it's incredibly low but does spike up and over 20 several times over the three-month sampling period. This is just one year but it offers an idea of what we could be missing with our once a month sampling.

SLIDE 32: PHYTOPLANKTON (Morrison et. al, 2008 – Relative Contribution)
Kalle: This graph also comes from Morrison et al 2008. Of the four components, chl a is probably the least significant but that is relative. All of the components are important, especially given the loss of eelgrass that we're seeing.
John: Just want to point out that the Morrison report concluded that light was sufficient for eelgrass growth. (see page 51 of Morrison et al)
Chris: First time I've seen these continuous monitoring data. These are high levels and indicate to me that this system is prone to algal blooms.

SLIDE 33: MATRIX TOOL
Kalle: So, for phytoplankton, I am marking it medium/high probability, medium impact and I have medium confidence.

SLIDE 34: TSS (TOTAL SUSPENDED SOLIDS – Concentrations at Adams Point)
Kalle: Let's talk about TSS. This is TSS at Adams point, where we see a significant increasing trend with the low tide values. Great Bay doesn't do any sampling at high tide, so I've stayed with low tide so that we're comparing apples to apples.

SLIDE 35: TSS (TOTAL SUSPENDED SOLIDS – Concentrations at Great Bay Station)
Kalle: TSS at the Great Bay station has a very different profile, however.

SLIDE 36: MATRIX TOOL
In terms of the matrix, I am rating TSS as a high probability and high impact stressor with a medium level of confidence.

SLIDE 37: CDOM
Kalle: This graph from Morrison et al (2008) was shown earlier and clearly shows that CDOM can be an important contribution to light attenuation.

SLIDE 38: MATRIX TOOL
Kalle: So, for CDOM, I rate it as a high probability, high impact stressor. The reason that I put question marks on the graph is that there is a precedent for CDOM and sediments restricting algal blooms. That's noted in the Morrison paper as well. So, thinking holistically, we have to consider the scenario where improved light benefits algae more than it does eelgrass, depending on the nutrient situation.

SLIDE 39: WASTING DISEASE
Kalle: We know that wasting disease can have a serious impact on eelgrass as shown in this graph. The late 80s values in dark blue are widely recognized to be caused by a large wasting disease event.

SLIDE 40: MATRIX TOOL
In terms of the matrix, I rate wasting disease as a medium-high probability but only medium impact stressor. And the confidence is low as we need more data to understand this stressor better.

SLIDE 41: SEDIMENT QUALITY
Kalle: Sediment quality relates to the geochemistry of the sediments themselves. When you get seaweed and/or phytoplankton blooms (see picture on the right), the dying algae can degrade the sediment, turning it hypoxic (low oxygen) or anoxic (without oxygen). This is very stressful for eelgrass, which has to adapt by sending oxygen down to the roots from the photosynthesizing shoot tissues. Also, anoxic sediment can lead to increases in sulfide, which can also lead to lower photosynthesis rates.
Jud Kenworthy also pointed out new research showing that fine sediment on the leaves of eelgrass reduces its ability for respiration (see picture on the left).

SLIDE 42: MATRIX TOOL
Kalle: We don't have very much data on this, but it seems likely that increasing levels of seaweed and occasional phytoplankton blooms make this stressor fairly likely. I rate it as a high probability and medium-high impact, but with low confidence.

SLIDE 43: MATRIX TOOL
Kalle: With regard to salinity, we know that big storms have dropped salinity levels significantly and that this can be a stressor on eelgrass.
Rich: The Mother's Day Storm dropped salinity to almost zero for almost two weeks.
Kalle: We don't have a lot of data on this, but I'm rating as medium probability and impact with low confidence.

SLIDE 44: RISING WATER TEMPERATURES
Kalle: As noted earlier, the rate of increasing water temperature in the Gulf of Maine is very high. Chris, you've looked at this quite a bit.
Chris: That's right. The rate of warming in this area is at least double the global average.
Note: Since the time of this presentation, errors were found in the water temperature data presented. Please contact Kalle for new data on water temperature.

SLIDE 45: MATRIX TOOL
Kalle: Based on this, I rate warming waters has a high probability and medium-high impact, but with low confidence due to lack of data, especially data from the shallow waters where eelgrass habitat is found (as opposed to the deeper waters where the buoys are located.)

SLIDE 46: NUTRIENT LOADING
Kalle: Nitrogen loading: This is the graph that you saw in the last SOOE, red lines are averages over 3 year periods for WWTF loading, blue lines for nonpoint source. 2005-06-07 jumps up related to flux and rain. To the right side of the vertical dashed line is the period from 2012 to 2016. Michelle Shattuck from UNH is working to breakout annual averages. The lines that you see there now are only estimates based on the work that Michelle has done so far. She is still hunting down data from some of the treatment plants and she still needs to model some of the non-point source load. So this is a preliminary assessment. The lower values are due to municipalities improving their effluent and also due to much lower levels of rainfall leading to lower run-off.
Note: At the time of the presentation, these 2012-2016 lines were accidentally plotted on the secondary Y axis, rather than the primary Y axis. The arrows indicate where these lines should have been placed.
Chris: Clarification on nonpoint sources, what does it include and what accounts for it dropping?
Kalle: As noted earlier, it includes atmospheric deposition, groundwater, septics, fertilizer, agriculture, etc. Main contributors are thought to be lower rainfall as well as improved stormwater practices at the municipal level.
Michelle: Data presented there are N loading from head of tide dam for 8 major tributaries. Red are the N loads from the 8 large WWTF. I still need to back out the estimated loads from the

smaller WWTFs. And I have to add in some loading from the area downstream of the head of tide.

SLIDE 47: NITROGEN LOADING
Kalle: This is the same graph as the previous, but I've added eelgrass acres (the green line) to the graph.
John: I just want to address the claim that phytoplankton are a reason the eelgrass is declining. Despite a factor of 3 change in the N loading level, the phytoplankton level didn't change. So, it doesn't seem that N is affecting the phytoplankton. N didn't make it go up and didn't make it go down.

SLIDE 48: NITROGEN LOADING
Kalle: A couple of issues there. As we've noted, we don't have the best phytoplankton record because we are only doing monthly sampling. The other issue is: how is nitrogen affecting seaweed abundance? Seaweed is less likely to get flushed out by tidal activity.
How does this relate to N loading? Nettleton 2011 (http://scholars.unh.edu/prep/374/) looking at Ulva at the stations depicted above and analyzed the seaweed tissue for nitrogen, and found that none of the Ulva tissue was limited by nitrogen. This indicates to me that nitrogen loading could be contributing to higher levels of seaweed, which have increased at our limited monitoring stations.
John: You ought to add N concentration as well as loading; the concentration data goes back to the 1970s and it's currently as low as it was back then when Art was originally out there for the first seaweed survey. Concentration is down lower than it has been in a long, long time.

SLIDE 49: MATRIX TOOL
Kalle: So, I have N loading as a medium probability and medium impact stressor.
From a management standpoint, of course, a key issue is: "Which of these stressors can we do something about, and we which are out of our control?"
That concludes my talk. Let's take a short break and then we can hear from John.

SLIDE 50: REVIEW OF GREAT BAY WATER QUALITY AND EELGRASS DATA
John Hall of the Great Bay Municipal Coalition

SLIDE 51: OVERVIEW
An overview of what I'll be discussing today.

SLIDE 52: UNIQUE GREAT BAY CHARACTERISTICS
Want to highlight that the Great Bay Estuary is very different from many of the other East Coast estuaries that people often compare it with. The main reasons for this difference are highlighted on the slide above.

SLIDE 53: HDR HYDRODYNAMIC MODEL – SALINITY AND CURRENTS (AUG 3-18, 2010 AVE)
The Coalition has worked with HDR, Inc. to create a 3D hydrodynamic model of the system. In this visual, the size of the arrows have to do with velocity. The larger arrows = larger velocity

SLIDE 54: HYDRAULIC CHARACTERISITCS
John: Because of these hydraulic conditions, the system has relatively short residence times. As you see in slide above, water in Great Bay has a residence time of around 3 days. If you count Great Bay and Little Bay together, it's higher. Notice that in the Upper Piscataqua River, the residence time is less than a day. Because of this, the ability of phytoplankton and floating seaweeds get washed out of the system much more quickly. In a different system with longer residence times, I'm sure you would have much higher phytoplankton biomass.

SLIDE 55: INFLUENCE OF CHARACTERISTICS ON EELGRASS DYNAMICS
The characteristics noted in the slide above are very important for understanding eelgrass dynamics.

SLIDE 56: PROBLEM IDENTIFICATION
Problem identification: The historical monitoring data on eelgrass cover indicates that cover is steadily declining, and biomass is claimed to be declining even more severely. Are we sure about the facts?

SLIDE 57: BASIS FOR FACTS (AERIAL PHOTOGRAPHY)
Fact: Aerial photography is the basis for eelgrass cover and density estimates. But ground truthing is limited (mostly on deep edges). Also, are we sure that seaweed wasn't present in the photos? We are calling everything eelgrass but are we sure about that?

SLIDE 58: REPORTED EELGRASS TRENDS
The higher graph (above) is from the 2013 PREP SOOE. Yes, if you start with 1996 it's big downfall. The second graph is from the NHEP (PREP's name before changed) Indicator Report from 2006. If you look at projected biomass it's even worse.

SLIDE 59: BIOMASS RELIABILITY CONCERNS
But we feel there are problems with these biomass assessments. They rely on unpublished data, the variability is unknown, and these estimates don't compare well with published studies. As you see in the table above, there's a one to one relationship until the highest density and then it triples. So, loss of higher density eelgrass has triple the effect on biomass. Is this reasonable?

SLIDE 60: BIOMASS LITERATURE
Let's look at some of the research in the literature. Carstensen et al. (2016) shows that the relationship actually flattens out and doesn't spike up. So, these published papers would argue that this relationship between cover and biomass is very different than what's been reported by PREP in the past.

SLIDE 61: BIOMASS TREND UNCERTAINTY
Here, we've plotted biomass using Carstensen values as well as for Great Bay Estuary, excluding wasting disease years. The point is that existing biomass estimates for Great Bay are not reliable.

Note from PREP: "Wasting disease" is known to always be present in the Great Bay Estuary, but in some years is worse than others. Up to this point, only 1988 and 1989 have been designated as "wasting disease years" for the purposes of calculating statistically significant trends. However, reports from Dr. Fred Short do indicate that wasting disease was an important cause of eelgrass loss in years 1995, 2000, 2001, 2002 and 2003. See "Eelgrass Distribution" reports from 2002, 2003 and 2004 at http://scholars.unh.edu/prep/
See also page 8 of the report, "NHEP 2006: Environmental Indicator Report: Critical Habitats and Species" located at: http://scholars.unh.edu/prep/161/

SLIDE 62: EELGRASS DENSITY CONCERNS
Regarding Eelgrass density as an indicator of eelgrass bed health. Again, this is based on aerial photography. Recent surveys have been in early August but it's unclear when the prior surveys were done. The point is that timing of the survey is critical to the results you get because the maximum density varies significantly within this period (August 1-October 15). It's not the same very year. The timing of the peak depends on conditions during growing season.

SLIDE 63: EELGRASS PEAK DENSITY TIMING
This graph comes from the SeagrassNet site (http://www.seagrassnet.org/percentcover/NH9.2) and covers years 2007-2016. It's obvious that percent cover really can change quite a bit between July and October. For example, in 2014, in July, there's no eelgrass at all but then it's close to 30% cover in October.

SLIDE 64: VARIABILITY IN TIME TO PEAK DENSITY (PERCENT COVER OF QUADRATS)
These data came from the same SeagrassNet website and show the amount of change between July and October.

SLIDE 65: EELGRASS ACREAGE CONCERNS
This slide is self-explanatory. Reports (such as this US Army Corp report) have noted that it's very hard to distinguish between eelgrass and macroalgae using aerial imagery. Cited report can be found at:
http://www.nws.usace.army.mil/Portals/27/docs/regulatory/Forms/Components%20of%20Eelgrass%20Delineation%205-27-16.pdf?ver=2016-05-27-131522-740
Matt: That report represents one viewpoint, but in speaking with people we've had map eelgrass (both Fred Short and Seth Barker), anecdotally, they say that they can distinguish, and that's based on groundtruthing as well.

SLIDE 66: 1996 EELGRASS COVER?
Let's talk about 1996. This was the year of peak eelgrass cover and the slide above shows a map of where eelgrass was that year. We have been trying to get the photographs on which this map is based for a long time but have been unsuccessful. This is showing eelgrass in some areas that grow more macroalgae than eelgrass. Is this all eelgrass? Sure, this deeper stuff is bound to be eelgrass. What about shallower areas? Maybe it's eelgrass, maybe it's not.

SLIDE 67: CONCLUSIONS REGARDING MAPPED EELGRASS ACREAGE
The main points are shown above. The last bullet point refers to the fact that seaweed biomass peaks later in the season so, when flights are done later than early August, these are even more confounded by seaweeds.

SLIDE 68: INDISPUTABLE FACTS
Let's transition to the facts that are indisputable. Since 2006, eelgrass has declined in Great Bay at all depths. So…what caused this to occur?

SLIDE 69: DES EELGRASS COVER WITH DEPTH TREND ANALYSIS
4/15/16 DES Memo. This is the graph you saw earlier, produced by DES showing eelgrass loss at all depths.

SLIDE 70: KEY INFORMATION TO CONSIDER IN EVALUATION OF TRENDS
John: As we evaluate trends, we really need to consider wasting disease and the Mother's Day Storm of 2006, both of which have not been acknowledged sufficiently in previous PREP reports.
Note from PREP: "Wasting disease" is known to always be present in the Great Bay Estuary, but in some years is worse than others. Up to this point, only 1988 and 1989 have been designated as "wasting disease years" for the purposes of calculating statistically significant trends. However, reports from Dr. Fred Short do indicate that wasting disease was an important cause of eelgrass loss in years 1995, 2000, 2001, 2002 and 2003. See "Eelgrass Distribution" reports from 2002, 2003 and 2004 at http://scholars.unh.edu/prep/
See also page 8 of the report, "NHEP 2006: Environmental Indicator Report: Critical Habitats and Species" located at: http://scholars.unh.edu/prep/161/

SLIDE 71: EELGRASS COVER ANALYSIS (PRE-2006 MOTHER'S DAY STORM)
Eelgrass cover analysis: all Great Bay Eelgrass for the period1998-2005 (when GB was not impaired for eelgrass). What you see is that "eelgrass" is able to grow to measureable cover in all habitable areas of Great Bay expect the deepest channel areas.
Ken Edwardson: Just a clarification on the usage of the term "impairment". Eelgrass wasn't looked at for impairment assessment until the 2000s, so to say it wasn't impaired during that period is a bit misleading. It may have been impaired, but we—DES—weren't looking at it yet.
Jud: For perspective, a group of scientists over the past 10 years did a global assessment world wide and there is a clear agreement in their work that impairment began decades ago. So, when you use that term…you have to be careful, because, to say these systems weren't impaired is not supported by the scientific literature. In all likeliness, the system probably was impaired. These systems were being impaired a long time ago.

SLIDE 72: MOTHER'S DAY STORM
This graph shows the typical 7-day average flow into the system, 2004 through 2008. Look at April (2006) and the Mothers Day flood, which happened May 9 just when the eelgrass are hopefully sprouting. Not only did we have the mother of all storms, but 3-4 weeks later we had another massive storm. Talking to Steve Jones and he said the Great Bay looked like chocolate

for almost two months. IN 2007, we had the Patriots Day storm, and, once again, it was early in the growing season. 2009 got wet again too by the way.

SLIDE 73: EXTREME FLOOD IN WATERSHED
This slide shows extreme flood in the watershed during the period of the Mother's Day Storm. We got 15" of rainfall in the basin.

SLIDE 74: EELGRASS COVER ANALYSIS (POST-2006 MOTHER'S DAY STORM)
So, let's compare the eelgrass map before the mothers day flood and then look at it from 2006-2013 period. It seems to recover in many places, but not in the red circles. Since 2006, eelgrass have not grown to measurable cover in several shallow areas (in total, >300 acres) that were previously eelgrass meadows.
Matt: I've overlaid this same thing, and the most northern circle…in my opinion, I would cross that one out. And same with the second one up from the bottom.
John: Can you share your analysis?
Matt: Anyone who wants to can visit the "Eelgrass mapper" and do this themselves. It's located at:
http://nhdes.maps.arcgis.com/apps/webappviewer/index.html?id=2792e57da2704867b164c17aee2dc43e
John: So, if the eelgrass losses are mostly in the shallows, does it make sense to say that they're light limited? I don't think so.
Ken Edwardson: Just want to point out that the largest oval on your map…most of that area is deeper than the other areas around it.
John: I think we need to better understand why eelgrass isn't growing there.
Ken Moore: Clarification, you mentioned earlier that you can't determine from aerial imagery what is eelgrass and what is algae. Could it be that in places you're saying it's eelgrass, it's actually seaweed?
Matt: Another point of clarification, the map that you showed as eelgrass, it's important to note the Quality Assurance Project Plan (QAPP) that was used didn't map eelgrass below 10% cover. We are not saying NO eelgrass there, but that it's sparse.
Wil: A question related to that. The dark areas can be between 10-100% eelgrass cover. You combine it because it comes and goes throughout the given period, but you could have lower densities in virtually any of these areas in a given year, correct?
John: In the post 2006 data, the eelgrass density is lower on average. Might make sense if you have less eelgrass to give you less seeds.
Jud: Kalle, you showed a slide in your talk that compared Seth Barker's assessment to Fred's. It's relevant to this discussion. Want to do it now?
Kalle: We have one comparison in one year, which was 2013, I believe that Fred Shorter was 87% accurate and Seth Barker was 94% accurate. You can read the results for each method test at:
Kappa/Barker = http://scholars.unh.edu/qapp/3/
Fred Short = http://scholars.unh.edu/qapp/4/
Matt: If we are talking about Great Bay proper, I think the two methods were around 300 acres apart. One point to note, the circle at the Squamscott in the lower left of the image…that was

one of Fred's areas that he reported as no eelgrass and Seth said yes it was eelgrass (above 10% cover).

SLIDE 75: EELGRASS ACRES OVER TIME
John: In this graph, we've plotted eelgrass acres and the red data points indicate years with known wasting disease outbreaks. So, in 2000-2003, you see the numbers coming down, but those are wasting disease years. When you run trend lines through the eelgrass acres before and after the Mothers day storm, you see that things have been pretty steady before and after the Storm, with the big break being the storm itself. After the storm, everything is down, including Portsmouth harbor.
Chris: Regarding wasting disease, can you clarify the source of the data? In a given year, do you have any sense of the intensity or variability of the disease?
John: We know that there were these outbreaks, based on Fred Short's reports, but we don't have additional detail. They don't say how prevalent the disease is.
Chris: I just want to point out that the wasting disease is reported as qualitative data (it's there always, but some years it's worse than others), but here you are using it quantitatively. What would these plots look like if you included data from the "wasting disease years"?
John: It would tilt down slightly, I believe, but still be relatively flat.
Note from PREP: "Wasting disease" is known to always be present in the Great Bay Estuary, but in some years is worse than others. Up to this point, only 1988 and 1989 have been designated as "wasting disease years" for the purposes of calculating statistically significant trends. However, reports from Dr. Fred Short do indicate that wasting disease was an important cause of eelgrass loss in years 1995, 2000, 2001, 2002 and 2003. See "Eelgrass Distribution" reports from 2002, 2003 and 2004 at http://scholars.unh.edu/prep/
See also page 8 of the report, "NHEP 2006: Environmental Indicator Report: Critical Habitats and Species" located at: http://scholars.unh.edu/prep/161/

SLIDE 76: CONCLUSIONS REGARDING EELGRASS DYNAMICS
So, after 2006, we have this new boundary showing a new growth pattern. You can find papers in the literature that show that huge storms like this can cause impacts that take decades to recover from. In view of that, it's not reasonable to use 1996 coverage as a basis for comparison. As noted above, over 300 acres in shallow areas are now not supporting eelgrass. Is it possible that the Mother's Day Storm brought in a huge supply of sediment and that has impacted the ability of eelgrass to reseed? I believe that Fred Short has sediment data for areas of the Great Bay? That would be really valuable to look into.

SLIDE 77: FACTORS KNOWN TO AFFECT EELGRASS
So, taking a step back, here are some of the factors that we need to consider.

SLIDE 78: AVAILABLE LIGHT IS NOT THE ISSUE
When we look at all these factors, we, the Municipal Coalition, believe that available light is not the issue.

SLIDE 79: DES EELGRASS ACREAGE – DEPTH ANALYSIS
Here, we've re-run the analysis that was discussed earlier, the one that DES did, but we ran it excluding all the periods when we know wasting disease was having an impact. What you see is that these slopes are no longer tilting downward but are fairly stable, both before and after the Mother's Day Storm.

SLIDE 80: LIGHT ATTENUATION
And when you plot eelgrass against light attenuation (Kd), you also see no relationship. In fact, the lower table shows that transmittance went way down from year 2008 to 2009 but you don't see a decrease in eelgrass; you see an increase. Again, no real relationship between eelgrass and light.

SLIDE 81: FACTORS INFLUENCING LIGHT
On this slide, I'm just reviewing some of the factors affecting light for eelgrass.

SLIDE 82: DISSOLVED ORGANIC NITROGEN AT GREAT BAY BUOY AT LOW TIDE (GRAPHS)
Let's look at Inorganic N vs. chl a vs. light attenuation: When N concentration was higher, light attenuation was actually better. And when N was lower, the chl a doesn't respond accordingly.

SLIDE 83: SUSPENDED SEDIMENTS (GRAPHS)
Sediments data offers another interesting "before and after" picture. The red line is the mothers day storm. Sediment didn't change before and after storm.

SLIDE 84: CANADA GOOSE GRAZING IN SHALLOWS
Let's talk about another stressor: grazing from Canada Geese. A 2007 paper by Short and Rivers confirmed that geese decimated a 25 acre eelgrass meadow at Fishing Island in Portsmouth Harbor.

SLIDE 85: WEATHER
We know that weather is causing stress to eelgrass, through extreme storm events such as the Mother's Day Storm. Beyond extreme events, the data suggest that rainfall patterns are changing, especially summertime rainfall patterns. We know that ice scour is an issue for eelgrass and was probably responsible for there not being any eelgrass in April of 2015.

SLIDE 86: MACROALGAE
Let's talk about macroalgae. In the next few slides, we'll review what we know from the sources shown here.

SLIDE 87: NETTLETON ET AL. (2011)
The Nettleton et al. (2011) report tracked seasonal growth on mud flats, but not where eelgrass is growing. What you see from that report is that macroalgae growth doesn't't really coincide with initial eelgrass growth. With regard to the nitrogen tissue analysis, the report noted that "Although DIN has increased dramatically since 1976, tissue concentrations in gracilaria have remained relatively stable."

SLIDE 88: MONITORING MACROALGAE

Dr. Burdick's monitoring work looked at macroalgae in late august and September. What you see is that both red and green algae are accumulating at lower elevations not where eelgrass is. Also, there haven't been any dramatic increases in macroalgae in the estuary from 2013 to 2015.

David Burdick: Just want to clarify that the reason there is no data in the lowest three boxes is we couldn't get out to that depth. We saw significant amounts of algae and we're finding them earlier and earlier in the season, as compared with Nettleton's findings. I would urge the group not to discount macroalgae because it can be important.

SLIDE 89: SEAGRASSNET STUDIES

The SeagrassNet data also show that seaweeds generally begin growth later than eelgrass, and the level of seaweed growth does not prevent eelgrass regrowth/seedlings. The main area of competition is in the shallows where ice scour may be more of an issue. Finally, we don't have any evidence that epiphytes are a significant problem.

SLIDE 90: EELGRASS STRESSOR RISK SUMMARY

This slide shows a review of all the stressors. We believe that the evidence suggests that phytoplankton, CDOM/NAP/TSS, macroalgae, epiphytes and nitrogen are all "low" probability stressors. On the other hand, we know that wasting disease, geese, severe weather, and ice scour are high probability stressors. We would consider temperature and sediment conditions as medium probability stressors.

Chris: Just want to point out that the points you list as high or medium are all based on qualitative data rather than quantitative.

Kalle: We're going to have to stop there, because we are out of time. We will pick up this discussion tomorrow.

TECHNICAL ADVISORY COMMITTEE MEETING MAY 10, 2017 DISCUSSION NOTES

Participants

Facilitator: Kalle Matso, PREP Coastal Scientist
Rachel Rouillard (PREP)
Abby Lyon (PREP)
Dante Torio (UNH)
Brian Giles
Jud Kenworthy (external advisor)
Ken Moore (external advisor)
Chris Gobler (external advisor)
Toby Stover (EPA)
Wil Wollheim (UNH)
Rich Langan (UNH)
Art Mathieson (UNH)
Paul Stacey (GBNERR)
Dean Peschel (consultant, City of Dover)
Dave Cedarholm (Tighe & Bond)
Erik Sawtelle
Lindsey Williams (UNH)
David Miller (resident, City of Rochester)
John Hall (consultant, City of Dover)
Bob Lucic (Sheehan, Phinney, Bass, Green)
Ken Edwardson (NH DES)
Ted Diers (NH DES)
Matt Wood (NH DES)
Rachel Stevens (GBNERR)
Michelle Shattuck (UNH)
Jeff Barnum (Conservation Law Foundation)
Alix Laferriere (The Nature Conservancy)
Ru Morrison (NERACOOS)
Fred Short (UNH)
Dan Arsenault (EPA)
Jean Brochi (EPA)
Phil Colarusso (EPA)
Regina Lyons (EPA)

Opening 10:05 AM

Introduction of "external advisors"
Jud Kenworthy (retired from NOAA; also served on 2014 Peer Review Report)
Ken Moore (Virginia Institute of Marine Science)
Chris Gobler (Stony Brook University)

SLIDE 92: BASIC AGENDA FOR WEDNESDAY, MAY 10 DAY 2

Kalle: Going over the basic agenda for the day, which is to use the matrix, discussed yesterday as well as on the next slide, as a way of organizing people's input on what stressors are most critical to manage with regard to eelgrass health.

SLIDE 93: MATRIX TOOL – OPENING COMMENTS

Kalle: The matrix you're seeing today is a bit changed from the one we showed yesterday. Last night, after yesterday's meeting, the three external advisors and I met to talk about the matrix and we are suggesting this modified version as a more helpful tool for today's exercise. In this version, we've re-arranged the different stressors on the x-axis and we've added some brackets to group some of the stressors based on the drivers. So, for example, salinity and TSS are related to stormwater run-off, etc. Also, you'll notice that there is no secondary Y axis on this version. We're trying to keep it simple today as we'll be pressed for time.

This is a tool to organize people's input. If you don't like it you can use the back side and write your thoughts. We aren't going to talk about the different processes. We will use your feedback as we write the state of our estuaries report and especially the longer Data Report, where we'll

have more room to discuss “minority” opinions and dissenting views. Also, I will lean heavily on our three external advisors. Any thoughts or comments?
Chris Gobler (external advisor).: If people have other factors that are not up there but should be, people should feel encouraged to include those in their matrix.
David B.: Do you want us to say what we think has been and will be affecting eelgrass in the last and next 5 years?
Kalle: I would rather you focus on what has been and IS happening…I’m less comfortable forecasting about the future.
Jud Kenworthy (external advisor): Can I point out a few things to keep in mind? The intent is not to be a stove pipe. Yesterday I noticed that people were confused about this idea of interacting factors. The thing to think about is 1) the Great Bay is an ecosystem, 2) think about ecosystem management, 3) think about how these factors might be interactive and additive.
Kalle: Can you say more about what you mean with the term “additive.”?
Jud: Best example is the Mother’s Day Storm. You have many potential stressors operating subtly, then you impose a disturbance that adds to the stressors or adds a new stressor. You have additive properties that are operating like they hadn’t before. Leads to a potential shift in how the different stressors exert pressure.
Chris G.: It’s important to consider the idea of resiliency in an ecosystem. Maybe eelgrass could handle any one of these stressors at a given time. But when many of the stressors are happening simultaneously, at different levels, you lose resiliency.
Paul Stacey: These comments are very important. The problem I have been having is that all stressors are leading to eelgrass, and eelgrass does not an ecosystem make. Can we take your advice and look at the ecosystem more broadly to get at this idea of “bio-integrity”?
Kalle: Good question, Paul. The advisors and I discussed this topic last night. Our view is that, yes, we are taking about eelgrass, but we are mostly talking about the ecosystem soup where the eelgrass lives. Eelgrass is a way to talk about our ecosystem. It’s an imperfect way, we agree, and it will be important to broaden this discussion at some point. Other questions? (see next slide)

SLIDE 94: MATRIX TOOL – MORE OPENING COMMENTS
Chris G.: One of the stressors up there has not been discussed very much. That is sediment quality and the idea that muddy sediments are rich in organic matter but can also be rich in sulfides, which can be toxic to eelgrass. They also kill off or deter bioturbating organisms, which help create more oxygen in the sediment. So…oxygen gets lower, sulfide gets higher, and kills off eelgrass. I understand that a lot of the Great Bay is comprised of muddy sediments. Organic matter can be from terrestrial runoff or produced in the system. Global research has shown this to be a co-stressor for eelgrass.
John Hall: Want to point out that yesterday, as TSS levels seemed to increase, there was a decrease in the number of oysters, especially in the Great Bay.
Michelle: Quick high level run through of how we fill out this matrix.
Kalle: Look at each stressor and ask yourself, for that stressor ,would you rate it Low, Low/Medium, Medium, Medium/High, High, in terms of the likelihood that it is exerting a stress on eelgrass.

Wil: Some stressors we may not be able to measure, like temp. It's still a stressor and we should still rate it.
Chris G: Yesterday we discussed that if a stressor is additive, such as the optical stressors, you might consider weighing them higher than you otherwise would.
Dan A.: Are we focusing on Great Bay proper?
Kalle: Yes.
Rich: I think invasive species should be added.
Kalle: Please add that to your matrix and we can discuss it later.

-----Break While People Work on Their Matrices-----

SLIDE 95: MATRIX TOOL – COMMENTS FROM LUCIC, COLARUSSO, SAWTELLE, MORRISON, BURDICK

(After 45 Minutes for People to Consider their Matrices….)
Kalle: Who wants to start?
Bob Lucic: I can start. I'm not a scientist. My approach to this has been to look at this given the gathered wisdom in this room…what is the information that will be helpful for the stakeholders. What I see, based on yesterday's discussions is that there are still a lot of questions, and there are some things that we know. For example, we know that in 2006, something catastrophic happened to our system; we had a storm and it had a profound impact. What we don't know is as a result of that – whatever the confluence of different stressors – is where we should be as a result of that storm. We have information before 2006, anecdotal and some that's based on data, but we have the ability now to look at and analyze what are the things that might be affecting the system at this point in time. And what additional info should we be gathering now, using 2006 as our baseline and getting a better understanding of what might be impeding a rebound – if that is happening. A storm such as the one that happened in 2006 might need 20 years for the eelgrass to come back. Looking at the information in that light, what are the things that we want to do over the next 3 years to increase our understanding?
Kalle: Thanks, Bob. Who wants to go next?
Phil Colarusso: The way I was thinking about the matrix was that everything on the right side that affects optical properties disproportionately affects resiliency. I do think Jud and Chris' earlier comments about the integration of stressors is an important point. Temperature is critical, but may not be significant alone. So, again, optical properties, because they have implications for the others should be higher or at the top of the hierarchy.
Kalle: Can you clarify if you're talking theoretically or specific to our system based on the data?
Phil C.; Looking at the DES graph of long-term eelgrass loss at different depths, going back to 1990s…I see two things: there's a long-term chronic pattern of loss and there's an acute episodic issue (the mothers day storm). I think it would be a mistake to ascribe significance to one and not to both.
Ru Morrison: I agree with about the chronic trend and the short-term episodic events. Need to concentrate on both.
Erick: Agree with observation that we need to look at this as a whole system. Is it possible that the Mothers Day Storm as reset the system, especially with regard to genetics, creating a new

niche for some species? David Burdick.: I don't think of the 2005-06 storms as the milestone that others are describing it as; I think the eelgrass did recover to some extent after the episode. About 2 years. A few other points…I don't agree with some of the statements I've heard about residence time. For example, I don't think a residence time of 1 day should discount the importance of phytoplankton. There's still enough time for phytoplankton to go up into Little Bay and Great Bay and affect water quality there. I think phytoplankton could be a very important component in my matrix.

SLIDE 96: MATRIX TOOL – COMMENTS FROM RICH LANGAN

Rich Langan: I appreciate the external panel comments about taking an ecosystem approach to this. What other events might have had an impact on eelgrass? I want to note that since 1993, we lost over 90% of the oysters in this system. Oysters are a major filter feeder, affect water clarity and light penetration. Those oyster habitats have not recovered. Sometime after 1993 is where you begin to see a chronic decline in oysters and eelgrass. We need to think about other changes we have seen in the estuary and how they are impacting the eelgrass matrix. So, I've added a few things to my version of the matrix. I have oyster decline on there with arrows going to TSS and phytoplankton, because less oysters means more of those, which affect light attenuation. I added invasive species, which s important in light of David Burdick's monitoring work showing how a lot of the seaweed in the system right now are invasives. But I also think about green crabs, another invasive species, which bioturbate—that is, dig up eelgrass—and they are predators on juvenile shellfish. We even have some blue crabs showing up now. As folks have pointed out, lots of these invasives are related to climate change.

Specifically referencing my matrix, I had a question mark on wasting disease and water temperature. I had geese and ice scour at "medium-low" because it really hasn't changed over the years. I rated storm effects such as salinity changes as "high." I gave sediment quality a question mark because we don't have data on that. TSS, CDOM and I rated as "high." I see phytoplankton levels as relatively low and not changing over the years and so rated that as "low." Seaweed I rated "medium," noting that much of it is invasive species. I rated both epiphytes and nitrogen as "low."

SLIDE 97: MATRIX TOOL – COMMENTS FROM WIL WOLLHEIM

Wil Wollheim: Regarding the eelgrass decline…to me, there are two competing views: are we in a new stable state or are we in a declining trend? It's not clear yet. We need more data to see. For a new stable state, you have some sort of positive feedback loop that keeps the ecosystem from recovering to previous levels. I think there's some evidence that we're seeing more wind-induced turbidity in the shallow areas, especially due to loss of eelgrass. This is the positive feedback loop: loss of eelgrass leads to more loss of eelgrass. It seems possible that we're seeing changes in the substrate and, in terms of where eelgrass loss has been permanent, this could be in response to the 2006 storm, and/or deposition of organically-rich matter. As others have pointed out: why are certain areas of the estuary no longer recovering?

More specifically, my version of the matrix rates wasting disease as medium/high, though we need more data. I have water temperate as medium/low. Geese and ice scour I have as "low" because there are not new disturbances. They happen periodically and I always have. CDOM as L/M because it tends to be during the off season, although you could have temp storms that flush things in. Geese as low because it's not a new disturbance. I don't rate salinity per se, but I do rate as "high" changes to substrate (organic matter, scouring, etc.) due to big storms. I think the combination of wind and turbidity—which TSS is part of– is "high," especially with less eelgrass around. With regard to phytoplankton, I rate that as "low," epiphytes as "medium/high" and seaweed as "medium." Since these are all exacerbated by nitrogen, my overall rating for nitrogen would be a "medium."

SLIDE 98: MATRIX TOOL – COMMENTS FROM TED DIERS

Ted Diers: A few quick thoughts…I added another axis on the right side of the diagram for some indication of whether this is an indicator that has changed overtime. John started that line of thinking in his presentation, but we sort of forgot about that and I do think it needs to be part of this analysis. The other thing I'll note is that the way you fill out this matrix could change dramatically depending on where you are in the estuary. I understand why we are generalizing to the Great Bay Proper, but it is a bit problematic, because there are different things going on in Great Bay. Unfortunately, a lot of our data comes from monitoring stations in or near deep channel, which is a bit different from where the eelgrass grows. That is clouding our view. Similarly, some of the key indicators that we are looking at, like phytoplankton and nitrogen concentration levels…we have only monthly measurements and some are not very long datasets going back in time. Drawing a lot of conclusions from those is challenging. Ken Reckhow, in particular of the four 2014 peer reviewers (http://scholars.unh.edu/rtr/1/), was clear about the issues of understanding those relationships based on the limited data we have. We still haven't gotten out of that cycle. Some data sets have high resolution and we are trying to compare them with data sets with low resolution.

More specifically, I agree that geese is L-L/M, and ice scouring has been happening forever, so I don't rate that highly. Regarding wasting disease, we don't know if it's happening more or less so I rated it as medium stressor, but low in terms of how much it's changed. I do think we need to b concerned about water temperature (medium/high) and salinity with regard to rainfall (medium rating.) Sediment quality…as Rich said we don't know a lot about this. We don't have Dissolved Oxygen on the matrix but it may be important and we don't know a lot about it outside the deep channels. With regard to CDOM…we don't know what it looked like 50 years ago, so it's hard to say, but I have it rated as "medium." For Phytoplankton, we have only monthly data, and the data from Ru Morrison's work (http://scholars.unh.edu/prep/110/) from 10 years ago…you see during some parts of the year the phytoplankton component was more important than in other times of the year. I have phytoplankton rated "medium." I do think we need to be concerned about seaweed increases in abundance and have that rated as "medium/high." Epiphytes I don't understand; I don't know what we have in terms of data. Finally, I did add to my matrix--as Rich did—that the loss of oysters is probably having an impact as well.

SLIDE 99: MATRIX TOOL – COMMENTS FROM ART MATHIESON

Art Mathieson: I have some comments based on studying seaweeds and water quality in the estuary since the 1970s. Currently, there are 12 introduced seaweeds in the Great Bay Estuary. Some are invasives. Some have been here since colonial times, others came in the last 6 years. Thinking about the graph that David Burdick showed earlier, he showed some early work from the late 1970s that showed the contributions of green seaweeds (such as Ulva) were higher than they are recently. More and more, we're seeing red algae, and a few of them are Asiatic species. For example, there are two Japanese species of gracilaria that are out competing the native species. Another red alga species, *Dasysiphonia japonica*, is one of the primary players that produces most of the biomass. On the shores, there is no question that these are dominating the low intertidal but they are in the subtidal as well. There's been a lot of work in Britain looking at the physiology and ecology of these species. Some of there are very tolerant to darkness and they have a high nutrient demand. They are very aggressive and very responsive to high nutrients. Same can be said for other species as well. You need to realize that there are a lot of things going on; there are organisms occurring now in the estuary that are more common south of Cape Cod. Organisms are moving in aggressively because of environmental stressors, and they're responding to nutrients and to open space in the ecosystem that they can take over. And they're responding to differences brought about by changing climate conditions. This was discussed yesterday; the Gulf of Maine is experiencing some of the most extreme changes in water temperatures across the world. We need to know about the biology of the major players. Talking about epiphytes, it's quite obvious to me from the field that microscopic epiphytes play a major role. They can be really small, but if they completely coat a blade they have a large impact.

Specific to the matrix, I have the following ratings: I have nutrients rated as "high." I have geese as "low" and ice scour as "low/medium." Storms and storm frequency is "high." TSS is "high." Phytoplankton is "medium/high," and seaweed is "high." Epiphytes are "high." I also have "light reduction" as "high" and introduced species (invasives) as "high."

SLIDE 100: MATRIX TOOL – COMMENTS FROM FRED SHORT

Fred Short: I've been studying eelgrass in the Great Bay Estuary since the early 1980s. I don't agree with the emphasis that some are putting on the Mothers Day Storm. As Dave pointed out, the eelgrass did recover somewhat from that event. In my field work, I'm seeing that the shallow areas are more affected by storms. These shallow areas have more seaweed as well, and storms move the seaweed around, stressing the eelgrass and resuspending sediment. Since many of these shallow areas have lost eelgrass habitat, there is a lot more bare sediment. And when it's not vegetated, nothing keeps the sediment on the bottom. Turbidity might be the biggest issue at this point, although I'm not sure it's always been the biggest problem. I was out in the field sampling a few weeks ago and we couldn't do the eelgrass count because the water was so turbid.

I rated geese as low as well as ice scour, especially if we have warmer winters. I rated Wasting Disease as medium-low because it's always present. It's at fairly low levels, and hasn't been really bad since 1988. I monitor it very closely, 6 months out of the year. The one in the 1930s wiped out eelgrass across North America and Europe. We lost species like scallops that haven't come back to the levels they were before. Eelgrass is very resilient to many of these stressors. I rated temperature as "Medium." Warming is a problem; I have put temperature sensors on the flats and the temperatures do sometimes come up to 35C (80-90F) but only for an hour or so, which shouldn't be enough to cause the problems we've seen. It's not enough for the sediments to warm up, which really causes problems. Eelgrass can handle the levels that we're seeing so far. I've rated storms as "medium." We do see an impact from some of the storms, like the Mother's Day Storm, but it's not catastrophic. Sediment affects …I do think sulfides are an issue; we have done studies on those, looking at different levels of organics in the sediment. Eelgrass can grow in high sulfide conditions, though, so I rated it "medium/low." But if there is something limiting the light, the sulfides do reduce growth. Long Island and Southern MA have really been impacted by this kind of combination. I ranked TSS as "high" and I think it has a potential for being a big problem. One way to bring TSS down is to do everything we can to bring the eelgrass back, since eelgrass baffles the water and leads to the settlement of floating particles. I rated "CDOM" low; from what I've seen, there is no evidence that CDOM has increased. It's a factor and plays a role, but no evidence that it has changed. Storms may make it worse for a short period, of course.

Phytoplankton I rate as "High," but it's complicated because of Interacting factors. In warmer temperatures, phytoplankton does better. TSS reduces the light to eelgrass, but it also reduces light to phytoplankton. When you have lots of TSS you have less phytoplankton. That's one of the reasons we don't see high chl a all the time; it's limited by TSS.
Seaweeds I rated "high"; they're affected by temperature, nitrogen, and invasives as Art mentioned. In recent years, we saw Ulva one year and Gracilaria the next year. Now, it's the new invasive Gracilaria everywhere. I ranked epiphytes as Medium, but this is very site specific. In Great Bay proper, we'd have tons of epiphytes if we didn't have the snails grazing on the leaves. They clear the algal epiphytes off the blades. Epiphytes should increase with temperature.

Finally, I'll say that, if we want the system to be healthier, we have to focus on those stresses that we can control. What can we have an impact on? Hoping we can get to that discussion.

SLIDE 101: MATRIX TOOL – COMMENTS FROM KEN EDWARDSON, NHDES
Ken Edwardson: As others have noticed, we need to differentiate between stresses that are chronic and those that are acute and, of course, which things have changed. I have geese and ice scour as things that happen fairly chronically and haven't really changed, so I rated them "low" although we don't have a lot of data on these stresses. With regard to the storm/salinity question, I rate it as a medium-low stressor, but it very episodic. I rate Water temperature as chronic and "medium." I rank nitrogen load as chronic and as "medium-high." Sediment quality…many people have pointed out this could be an issue, but the data is not very strong. On the other hand, there are cascading responses that could fit our system; I rate it as "medium." I rank Wasting Disease as medium-low; it's always been there at some level. I ranked CDOM as medium-low, because it's at its worst just before and after the prime eelgrass growing season. I see TSS as both chronic and episodic and both a stressor and a response to

conditions; I rate it as somewhere between "medium" and "medium-high." I see Phytoplankton also as both chronic and episodic, and I rated it medium-high as well.
Finally, I want to point out that out system is really different depending on exactly where you sample. A lot of our data is taken from buoys that are sitting in deeper channels and are experiencing different conditions than are happening where the eelgrass grows. In the photo on the slide above, which comes from the 2016 National Agriculture Imagery Program, you can see how distinct the dredged channels are from the shallower areas, and you can see that different things that come off the mud flats. There are areas where the water is greener and may be experiencing algae blooms and other areas that are brown because of moving sediment.
It's also very time-specific and I think we miss a lot when we rely only on monthly grab samples.
Finally, I do agree with what Rich Langan said earlier about oysters; it's important to keep in mind what we have lost and the possibility that this has cascaded into other variables.

SLIDE 102: MATRIX TOOL – COMMENTS FROM PAUL STACEY, GREAT BAY NATIONAL ESTUARINE RESEARCH RESERVE

Paul Stacey. I have to say that this matrix didn't work for me. It comes back to the end point. I worry that we're talking about stress too narrowly in terms of really honing in just on eelgrass. Our aim should be biological integrity for the whole system…not just one species. So, I had to make changes to the matrix to make it work for me. Rather than focus on nitrogen, I thought about nutrients more broadly as Nitrogen, Phosphorus, and Silica. For nutrients, we probably have "medium-high" level of stress. I say that not using eelgrass as an endpoint, but rather just looking at the amount of nutrients that flow into the system. I think toxic chemicals are probably a "medium-low" level of stress. I added a category called "Competition for space," which is a catch all, but it's important. We have sediments where there used to be eelgrass meadows; where there used to be oysters, we now have invasive seaweeds. Competition for space is the outcome and most important reflection of biological integrity. I rate that as "High" because there is a lot of competition. I rate "CDOM" as low or no stress. I rate Ice scour as low stress because the system has adapted to it.

I rate salinity and other storm effects as "medium." The question of sediment quality is important and I rate that as a medium level stressor. Light issues seem to be a medium-low level stressor, and I put TSS in the same category: medium-low. The issue of new invasive seaweeds is "high."

I do think we have more stress from nutrient loading than the system should be exposed to, and we need to decrease that stress to result in better biological integrity. But that's not the only thing we need to do.

SLIDE 103: MATRIX TOOL – COMMENTS FROM JUD KENWORTHY, EXTERNAL ADVISOR TO THE PREP TAC

NOTE: After each of the external advisors spoke, Kalle asked the other two if there was any aspect of what was said that either advisor disagreed with in any way. All three advisors

agreed 100% with the verbal comments made by the others. However, note that the matrix ratings were not exactly the same.

Jud Kenworthy: I'd like to talk about the biology of this plant and how it plays into this story. It's critical to keep this whole story in the context of multiple stressors and interacting factors. First of all, eelgrass is a clonal plant; it divides at the meristem and reproduces vegetatively. These patches aggregate and you get meadows of eelgrass. But eelgrass is also a flowering plant; it produces seeds, and some seeds germinate right away, turning in to flowers. Others get buried and don't germinate until later. This basic life strategy was described a long time ago as the biennial life history. What happens, demonstrated over the world, is that the plant divides, spreads out, and in the second year of growth it becomes a flower and that's the end of its life. There's a high degree of mortality, because once they produce flowers, that's it. So when we talk about meadows of eelgrass, they may be perennial, but the plants themselves are not; they're biennial. It's further complicated because some of the plants turn to flowers and some don't. For example, West coast eelgrass plants don't flower at all; they only reproduce vegetatively. In North Carolina and Canada, plants only live one year. In the case of Great Bay Estuary eelgrass, I would say that reproduction--sexual reproduction--is very important. When you look at the fluctuations of eelgrass populations over time for this system, you cannot explain those fluctuations from vegetative reproduction alone. Great changes in area are a result of seed propagation or the inability of seeds to establish themselves. Every seed produced this year either germinates right away or the next year, and that's it. The viability of seeds is very low, around 1%, so the plants produce thousands of seeds but many of those don't propagate. Some of them are moved up and down in the sediments to a non-optimal germinating depths.

So, if you think about the life history of this plant, there are several points in the life history where there are different things that affect it. Seed production requires a lot of energy. If you lower the light just a little bit, you reduce the # of flowers you produce. Seedlings are different from clonal plants, which can share resources; maybe some plants are struggling so they get more carbohydrates from other plants connected through the root system. But a little seedling doesn't have that capability. Studies have been done worldwide, and they show that the young seedlings need to get to a certain size before the clonal process can happen. They need a lot more light. Sulfides, as many folks have talked about, are toxic to seedlings. If you alter the sediment quality and you affect the reproductive capacity of the plant, there will be consequences. My point is that these critical stages of life interact with a lot of factors. Nitrogen is important but nitrogen alone isn't going to be the story. It could be the main story if the leaves of seedlings are getting covered with macroalgae or epiphytes. But gain, little steps along the way affect the seedlings. You can't isolate one stressor and say, "this is the one." Any future thoughts about management need to think about the reproductive life history, because there is a Law of diminishing returns that is completely driven by the math of seed-based reproduction. Unless the plants adapt into annual plants or you increase the survival rate of the seedlings…your capacity to rebound from disturbance will decrease over time.

Matrix ratings (provided electronically after the meeting): Geese, ice scour and wasting disease are all low on average but could be high in an acute event, in combination with other factors.

Same goes for storms and salinity. Salinity can also be a chronic stressor. Water temperature rated "medium-low." Sediment quality/organic matter/sulfide is rated "medium-high." It's labelled as a chronic (slow) stressor. TSS, CDOM and Phytoplankton are "combined to get to light" as one on the matrix and rated "high." Seaweed is rated medium-low but "trending up." Epiphytes are rated medium-low.

SLIDE 104: MATRIX TOOL – COMMENTS FROM KEN MOORE, EXTERNAL ADVISOR TO THE PREP TAC

NOTE: After each of the external advisors spoke, Kalle asked the other two if there was any aspect of what was said that either advisor disagreed with in any way. All three advisors agreed 100% with the verbal comments made by the others. However, note that the matrix ratings were not exactly the same.

Ken Moore (external advisor). I really appreciate being here and hearing from everyone and reading all of the information to re-familiarize myself with the Great Bay Estuary. I first came here in the 1980s. It's a really great system and it's interesting to see how much things have changed. One reason I was asked to share some thoughts was because I've been in a lot of different systems around world and I've been studying seagrasses for a long time. Even though this system is special, it does also share a lot of characteristics with other estuary and lagoon systems around the world and certainly the US. Typically what we see – and have seen in other places – is that systems get into trouble as development increases, but I also want to say that this system can recover. We have seen that in other places where the management efforts to reduce nutrient and sediment inputs to the system have been significant enough to recover from the downward trajectories. Earlier, Paul Stacey asked about the focus on eelgrass? For Chesapeake Bay, where I work, eelgrass is a small component but it gets a lot of focus because it can serve as a great indicator of the health and resilience and the overall condition of the system. Eelgrass is often referred to as the canary in the coal mine. I wouldn't discount eelgrass as being important from that perspective.

Looking at the information on this system, nutrients are one of the stressors that has been important in all of these coastal systems. When you look at the amount of nutrient loading on surface area basis, this system is getting around 5 times the loading that the Chesapeake Bay is exposed to.

Kalle: I want to point out that the assessments you're referring to pre-dated the recent reductions from the wastewater treatment plants.

Ken: That's true and it's great that you're addressing this issue, but I believe the loads are still quite high. That stands out. Other things we see in this systems…when you look at the data, keep in mind that it's not the average values that are important; many times the things that matter manifest themselves in episodic events. The data show that, overall, phytoplankton levels are fairly low, but that's based on monthly grab samples, and when we look at data that has more frequent sampling, such as the Morrison report (Slide 31 and [http://scholars.unh.edu/prep/110/)](http://scholars.unh.edu/prep/110/), we see that phytoplankton levels can get quite high. Nitrogen input levels are high; it's coming into the system and it's doing something. It makes things grow. One of the things it affects is macroalgae. That's important. Macroalgae and seagrasses don't compete real well. Seagrasses do not need a lot of Nitrogen in the water column. They are well adapted to recycling resources. Eelgrass evolved in systems where N was low and there was relatively clear water. So, they get out competed by macroalgae. We're seeing the same species (such as Graciiaria) in the Carolinas that you're seeing here. I think it's important to step back and look and realize that these are the drivers that we see around the world. The first step as managers is to ask: what can we control? There are some things that we can control. Point sources are something we can control. But there are other sources, nonpoint sources, and ultimately they need to be addressed.

As others have pointed out, the system is under stress. Everything up on the matrix…they are additive. A stressed system doesn't do as well handling any one of those stressors than it would if it were healthier. That's how we are seeing responses in other systems. Recovery is hard and sometimes needs better conditions than they were just before the system declined, because now you have all of these positive feedback loops. Need clearer water so seedlings can grow better and expand back into areas where they once were. Water quality targets may need to be set higher than they were before the decline so that the system can recover. We've talked about changing temperature and climate; we're having the same conversations in the Chesapeake Bay. The climate is changing and it's warming. It's a threat multiplier. We are the threat in one way or another, and a changing, warming climate adds to that. Respiratory requirements for eelgrass go up in warmer weather. If we have clear enough water and a good enough environment the eelgrass will do okay. Based on what I've seen, you're not at a point where the eelgrass is being killed because it's too hot. On the other hand, there is a relationship between temperature and eelgrass growth reduction. Growth starts to decrease at around 18 or 17 degrees C.

Finally, as others have noted, what we need more of is a way to understand in a more detailed way the spatial and temporal factors that are very important.

Matrix ratings (provided after the meeting): Geese, ice scour and wasting disease were not on Ken Moore's matrix. Temperature rated "medium." Nitrogen rated "high." Salinity rated "low." Storms rated "medium." Sediment quality/organic matter/sulfides rated "medium-high." TSS rated "medium; high." CDOM rated "medium-low." Phytoplankton rated "medium-high." Macroalgae rated "medium-high." Epiphytes rated "medium high."

SLIDE 105: MATRIX TOOL – COMMENTS FROM CHRIS GOBLER, EXTERNAL ADVISOR TO THE PREP TAC

NOTE: After each of the external advisors spoke, Kalle asked the other two if there was any aspect of what was said that either advisor disagreed with in any way. All three advisors agreed 100% with the verbal comments made by the others. However, note that the matrix ratings were not exactly the same.

Chris Gobler (external advisor): I'll go over my matrix rating and offer some other thoughts as well. I rated ice scour and geese low because it hasn't been changing dramatically over time. No reason to think it's more intensive now. I have wasting disease at "medium-low" particularly after Fred said it's always there, although we know that big pulses (1989 and 1930) can cause significant loss. I rated temperature as “medium-low.” In my experience, you need 2 weeks of 24C water temperatures to knock back eelgrass. Given the tidal exchange in this system, you aren’t there yet. I rated storm events as “Medium.” They can be catastrophic but they are infrequent. I rated CDOM also as “Medium.” It’s not changing as much. I rate Sediment/organic matter/sediment quality as ”medium-high.” I recognize that we don’t have enough information but we know that this system has a lot of muddy sediments, and it’s very easy for a positive feedback loop to get set up such that it becomes very difficult for eelgrass to move into those areas.

In rating phytoplankton, it’s important to keep in mind that this system is very dynamic and responding to wind and freshwater inputs, which also impact light. Also, as has been noted before, there is most likely an interesting dynamic happening between high TSS levels keeping phytoplankton levels lower than they would be otherwise. Phytoplankton might be important but episodically rather than chronically. In the end, I rated phytoplankton as “medium-high.” I rated epiphytes as “medium” as they can be an issue. If snails keep the epiphytes in check, that’s great, but what happens if you lose those snails? The science indicates that the Great Bay Estuary highly unstable right now. If it’s a single herbivore keeping the epiphytes at bay, it may be important to ask, what if you lose them? I rated TSS “High” based on the sensor data that we’ve seen. The data indicate an increase in TSS over time, and the absolute levels of TSS are quite high. That’s a big concern. Macroalgae is a big issue; I rated it “high.”

I’d like to make some additional points about macroalgae. We’ve already discussed that they can block out light from seagrasses, but there are other issues: First, high macroalgae abundances make the sediments more organically rich, which can stress eelgrass in a couple of ways; second, macroalgae themselves—including Graciliaria—have allelopathic compounds to help them outcompete other plants. Those compounds are present. Ulva actually restricts eelgrass with the release of allelopathic compounds. Third, CO_2 levels in the water are higher today than they were years ago due to greenhouse gas emissions. Estuaries like Great Bay can have seasonally elevated CO_2 levels. I recently completed some research that eelgrass benefit from CO_2, but macroalgae does too and macroalgae tends to win out. For all of those reasons macroalgae is a big concern.

Switching gears to discuss nitrogen loading rates…a few years ago, I participated in a study looking at N loading from multiple ecosystems. N loading rates to Great Bay were quite high on a per area basis. It was one of the higher estuaries in terms of N loading. And it was really high when you looked at it on a per volume basis, rather than per area. The ecosystem feels the nitrogen from the volume because it’s a function of how much water is in the system. Because of the shallow nature of this ecosystem, it’s more vulnerable to N loading. You can compare this to Long Island Sounds, which is 200 ft. deep in most places, and it takes a lot more nitrogen to cause problems.

My final point…moving forward there are going to be things that you can do to increase the health of the system and others stressors that you can’t do anything about. This is key from a management point. It’s important to see that there are multiple stressors and they are adding up to have an impact. The approach that needs to be taken is: of all of these things, what can we do something about to improve the condition? The others you need to release like a balloon.

SLIDE 106: NOTES FINAL DISCUSSION SEGMENT (1)

Ken Moore: I appreciate and agree with Chris' comments. It reminds me of another point I meant to make. We talked about how this system has good flushing due to the inputs and tides. I want to point out that this is also a stress on eelgrass. In general, seagrass would rather have no tide change. With a high tide change, eelgrass has to exert energy adapting it's photosynthesis processes to the changes in light. During high tide, the plants have low light and they don't get quite enough. At low tide, when they're laying on top of mudflats are on top of the water, they're getting much more light and have to adapt to that…back and forth. Keep that in mind for this community.

Paul Stacey: A follow up on Chris' comment about N loading rates for Great Bay. How much of the loading is mitigated by the flushing? Long Island sounds has a longer residence time.

Chris: The macroalgae can integrate the N regardless of the tide, because it's not getting flushed out. It has a huge effect on phytoplankton, of course. If you didn't have the tidal exchange you have, I'd expect massive phytoplankton blooms in this system.

David Burdick: Ken mentioned that our system was unstable. I think we need to consider that we're at a tipping point, changing from one kind of dynamic system to another. For example, now that we have more bare mud areas—due to less eelgrass and less oysters—it's possible that wind and wind-driven turbidity is more important. As others have said, the road to recovery isn't the same as the road to ruin. We'll need more actions to reduce and break those interactions and feedback cycles if you want your system to go in a certain direction.

Finally, One thing people haven't talked about is top down control from fish. A lot of the big fish that we used to have in this system aren't here anymore. That may be having an influence.

SLIDE 107: NOTES FINAL DISCUSSION SEGMENT (2)

John Hall: I'd like to make a few points. We do have significant information on phytoplankton growth and I haven't seen the evidence to say that phytoplankton blooms are occurring. I believe I heard someone earlier say that we had levels as high as 35 mg/L for chlorophyll A….again, I'm not sure where that's coming from.

Chris Gobler: I'm not sure who made that reference. I saw that the level was above 20mg/L, and I was basing that on the Morrison report. EPA does consider levels higher than 20 as being an indicator of eutrophic conditions.

John: The data don't show elevated chl-a. I've never seen data showing that. Secondly, I want to address the claim that recovery requires better conditions than before the decline occurred...The system has recovered from dramatic shifts without additional improvements, so I'm not sure that notion carries weight. I appreciate Ted's earlier comment to really focus on what's changed. If a potential stressor didn't change, then I think you should rate it low. As far as I can tell, we don't have data to say that CDOM, chl a, and TSS have changed, so why are we rating them as high?

In terms of big changes, what did change is that the nitrogen concentrations have dramatically decreased. We are lower than we were in the 1990 and as low as concentrations were in the1970s. I don't see the evidence that Chl-a changed nor that macroalgae has changed. I'm also frankly befuddled about the claims that nitrogen loading rates are too high, based on other systems. In 2007, the PREP technical committee looked at these suggested levels from others systems and said they aren't appropriate for the Great Bay Estuary system. We just don't see this system responding to nutrient loading levels the way that we see in other systems respond. Also, a point about low tide measurements…we keep using all of this data that's only taken at low tide. As a result, we're not giving ourselves a full picture of what eelgrass is exposed to through the full tidal cycle. At low tide, everything drained out of the streams so the concentrations are going to be higher. At high tide, we have substantially lower chl a levels. Finally, I presented serious information on the reliability of the eelgrass acreage changes by depth. We are making big decisions based on these data and I have serious problems with how these data were collected.

SLIDE 108: NOTES FINAL DISCUSSION SEGMENT (3)
John Hall: I'd like to use a couple of more slides (see above) to make some additional points about Portsmouth Harbor. If you look at eelgrass cover in Portsmouth harbor, there wasn't a dramatic decline in 2006 like there was in other parts of the system. Whatever happened in Great Bay did not occur in Portsmouth Harbor. But still, this area has seen a steady decline in eelgrass. And yet the water quality in Portsmouth Harbor is excellent; it's the best in the system. But eelgrass continues to decline.
I think that bringing in the situation of the Peconic Estuary in Long Island is helpful.

SLIDE 109: PECONIC ESTUARY – ORIENT POINT
In the Peconic Estuary, there are two locations where water quality is excellent; these sites are right on the Atlantic Ocean on the coast. One of them is Orient Point where they've seen a 50% reduction in eelgrass.

SLIDE 110: PECONIC ESTUARY – CEDAR POINT
The other is Cedar Point. It was looking good in 2004 and then began to diminish, similar to what happened in Portsmouth Harbor. Now, nitrogen is low at these sites. You have, basically, clean ocean water cruising through there. But there's actually a worse pattern of eelgrass loss here than in Great Bay.

SLIDE 111: WHAT DOES LI DATA SHOW?
So, my question is: Is it a biological agent that's killing the eelgrass? Disease? Something from ballast water? Clearly, it's not nitrogen at those locations.

SLIDE 112: NOTE FINAL DECISION SEGMENT (3)
Chris Gobler: I'd like to speak to that data and some of those points. I've been working in that system for 25 years. Nitrogen loading is, in fact, definitely the issue. The declines in that system are happening in areas with the longest retention times. We know that the nitrogen levels in the groundwater for those systems have increased by 60% in the last two decades. In that

system, the areas with the nitrogen loading have lost their eelgrass. The story gets a little more complex because they've been trying different techniques for eelgrass restoration in those places: some are working well, and some have been shown not to work. All the sites now have switched restoration methods and the thought is that they are working better.
The other issue in that system is that we clearly have water temperatures rising more than 3 times the global average, since 1982. Connected to that, we are seeing the occurrence of what is called a "rust tide," which is a kind of harmful algal bloom. But this organism is not coming from ballast water; the organism has been present since the 1960s, but the environment, with the warming, has become more selective for this HAB and so it's become more of an issue. Often times in ecology, the organisms exist at low levels everywhere, but then the environment selects what will succeed.

SLIDE 113: NOTES FINAL DISCUSSION SEGMENT (4)
Fred: I want to address some of the points made about "no change in TSS" and no change in N coming into the system. If you look at some of the data, you can make that conclusion, but if you look at it all, I don't think you see that. PREP's data on actual loading only goes back to 2003, but data in 1988 and again in 1992 show that loading N was only around 700 tons/year. But in 2003, it was 1,200 tons per year and was still that high in 2012. So that's a clear change that's been happening over time. I believe that level of nitrogen input to the bay is a huge problem.

Portsmouth Harbor has been brought up as a comparison. That is a different situation and, yes, the water quality there is excellent, but only excellent when you compare it to the Great Bay. On an incoming tide, the water there is quite clear, but if you look at it on an outgoing tide, you see that the water isn't clear. A few decades ago, that outgoing water was much bluer than it is today; today it's greener. What I've seen there is that eelgrass has decreased slowly and it's moving to shallower areas. That's how eelgrass responds to small reductions in light. It can't grow quite as deep.

SLIDE 114: NOTE FINAL DISCUSSION SEGMENT (4)
Toby Stover (EPA): I just want to say, on the topic of chlorophyll-a…the monitoring data clearly show there are high levels of chlorophyll a. This is well documented and throughout the estuary.

CLARIFICATION: After the meeting, Toby noted that the data source for this statement was: "NH DES. 2017. Technical Support Document for the Great Bay Estuary Aquatic Life Use Support Assessments, 2016 305(b) Report/303(d) List," which can be found at:
https://www.des.nh.gov/organization/divisions/water/wmb/swqa/2016/documents/r-wd-17-12.pdf

Jean Brochi (EPA): I'm hoping for some clarification from PREP about the focus of this meeting. I'm a bit confused. I know that PREP encompasses the entire Great Bay Estuary, as well as the Hampton-Seabrook estuary. On the other hand, it's been said that we would focus today on just Great Bay, because it would be too much to discuss the whole estuary. But in the last 10 minutes, there's been a lot of discussion about Portsmouth Harbor. So, it would be great to clear that up and I know that other folks were hoping for more clarification about the "cross cutting section" and how this all relates to PREP's CCMP (comprehensive conservation and management plan.)

SLIDE 115: NOTES FINAL DISCUSSION SEGMENT (5)
Rachel Rouillard (PREP Director): Thanks, Jeannie. Good questions. First, I'd like to thank everyone for coming to these meetings and the work that you all have put in behind the scenes. I don't what it to go without saying that most of the people in this room are providing input that's helping us wrestle with these complex issues. I want to acknowledge that the conversation has lots of different perspectives and that can cause stress. There is some discomfort with this process, but some level of stress and conflict is part of a good constructive process.

The State of Our Estuaries Report, coming out on December 8, 2017, will not be a silver bullet. It's 5 years of data, based on essentially the same indicators we've been tracking. It moves us down the road, as we try to understand how to make the right investments in research and continue to work together.

Jeannie brought up the cross-cutting section of the report…we have more than 20 indicators that we have and will continue to track. What is different is that we want to use the front and back sections of the State of Our Estuaries Report to to characterize new issues, changes that have occurred, and things we have learned from these discussions amongst ourselves and from our external technical advisors. The cross-cutting section will not be about Great Bay only, but we did want to focus the conversation over the last couple of days so that we could dive a bit deeper into some of these issues. In some ways, the cross-cutting section will mirror the conversation we've had: looking at issues of key habitats, such as eelgrass, in order to have a conversation about the overall health of the system. The cross-cutting section also allows us to bring in some other parameters that we don't usually track, such as: changing precipitation patterns and CDOM levels.

Finally, I want to address Jeannie's question about the CCMP or Comprehensive Conservation Management Plan; I know that a few people are unfamiliar with that. It's a 10-year management plan that we developed with our stakeholders in the region. There were over 150 participants, state agencies, local partners, citizens, etc. to develop action plans for water quality and management. It goes through 2020. We will start revisiting and modifying that plan in January 2018. What we will do is identify the action plans where there are questions. Did we get this done, why not? Should there be new goals? The discussion from these TAC meetings will set the table for those conversations for the next 2020-2030. If your ideas and feedback don't get incorporated in the SOOE it will be used for the CCMP conversation.

SLIDE 116: CONCLUSION
Rachel Rouillard (PREP Director): Once again, thank you to everyone who participated over the next couple of days. PREP greatly appreciates your collaboration.